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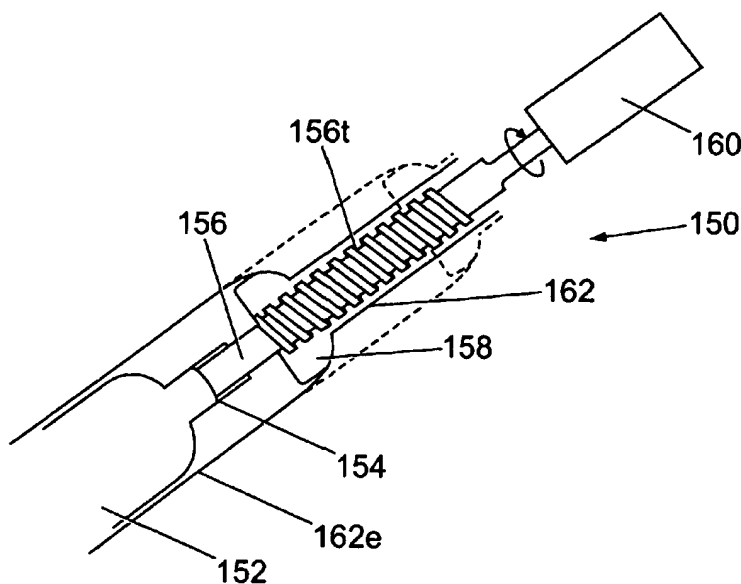
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(54) Title: APPARATUS FOR AND A METHOD OF EXPANDING TUBULARS



(57) Abstract: Apparatus for and a method of expanding tubulars, and particularly tubulars or a string of tubulars that have one or more perforated portions and one or more non-perforated portions. In one embodiment, the apparatus (150) includes an inflatable element (e.g. a packer 152) that has a shaft (156) rotatably coupled thereto so that the shaft (156) can rotate relative to the inflatable element (152). An expansion cone (158) is threaded with a threaded portion (156t) of the shaft (156) so that it moves along the threaded portion (156t) upon rotation of the shaft (156) relative to the cone (158).

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1 "Apparatus for and a Method of Expanding Tubulars"

2

3 The present invention relates to apparatus for and a
4 method of expanding tubulars, and particularly, but
5 not exclusively, to tubulars that include a
6 perforated or slotted portion and a non-perforated
7 portion.

8

9 The invention can also be used with combination
10 strings that include non-perforated tubulars and
11 slotted or perforated tubulars that are coupled
12 together to form a string.

13

14 Use of the term "tubulars" or "tubular members"
15 herein will be understood to encompass any tubular
16 or tubular member, such as casing, liner, drill pipe
17 etc, and other such downhole tubulars.

18

19 It is known to expand tubular members to increase an
20 outer diameter (OD) and/or an inner diameter (ID) of
21 the tubular member. This can be done by radial
22 expansion of the member, where a radial expansion

1 force is applied to a portion of the member to
2 radially expand it. The radial expansion force is
3 typically applied using an inflatable element, such
4 as a packer.

5
6 Alternatively, the tubular member can be expanded by
7 applying a radial expansion force to the member so
8 that it undergoes plastic and/or elastic
9 deformation. In this case, the radial expansion
10 force is typically applied using an expander device,
11 e.g. an expansion cone, which is pushed or pulled
12 through the tubular member. An OD of the expander
13 device is typically the same as or slightly less
14 than the final ID of the expanded tubular member.

15
16 It will be appreciated that use of the terms "radial
17 expansion" or "radially expanded" herein encompasses
18 both of these options.

19
20 The tubular members are typically used to line or
21 case an open borehole, but have other uses as they
22 can be used, for example, to repair damaged portions
23 of casing or liner.

24
25 The tubular members can include slotted or
26 perforated portions where the slots or perforations
27 expand into approximate diamond shapes or the like
28 when the tubular member is radially expanded. The
29 slotted or perforated portions can be used, for
30 example, as a sand screen at or near a payzone of a
31 formation or reservoir to prevent sand and other
32 such contaminants from being mixed with hydrocarbons

1 that are recovered from the payzone or reservoir.
2 The slotted or perforated portions can also be used
3 to allow fluids from the payzone or formation to
4 flow into the tubular member so that they can be
5 recovered to the surface. Use of the term
6 "perforated" herein is intended to encompass slots,
7 apertures or the like in the tubular member.

8
9 According to a first aspect of the present
10 invention, there is provided apparatus for expanding
11 a tubular member, the apparatus comprising an
12 expander device that is capable of generating
13 different radial expansion forces to expand
14 respective portions of the tubular member.

15
16 According to a second aspect of the present
17 invention, there is provided a method of expanding a
18 tubular member, the member including first and
19 second portions, the method comprising the steps of
20 running the tubular member into a borehole and
21 radially expanding the first and second portions in
22 the borehole using an expander device, wherein
23 different radial expansion forces are exerted on the
24 first and second portions respectively.

25
26 The tubular member may have separate portions that
27 are radially expandable to different extents.
28 Typically, the respective portions comprise first
29 and second portions. The first portion typically
30 includes at least one perforated portion. The
31 second portion typically includes at least one non-
32 perforated portion. In most preferred embodiments,

1 the perforated portion can expand to a greater
2 extent than the non-perforated portion. Typically,
3 the radial expansion force required to expand the
4 perforated portion is less than the radial expansion
5 force required to expand the non-perforated portion.
6 The tubular member may comprise a string of discrete
7 members having perforated and non-perforated
8 portions. The discrete members are typically
9 coupled together by any conventional means, such as
10 welding, screw threads etc.

11
12 "Perforated" as used herein means that the member is
13 provided with one or more apertures, slots or the
14 like. Typically, a plurality of apertures or slots
15 are provided. It will be appreciated that "non-
16 perforated" as used herein means that the member
17 does not have apertures or slots therein.

18
19 One embodiment of an expander device comprises an
20 inflatable element having a shaft rotatably attached
21 thereto. The shaft can preferably rotate relative
22 to the inflatable member. A bearing or the like is
23 typically located between the inflatable element and
24 the shaft. The inflatable member typically
25 comprises a packer or the like. At least a portion
26 of the shaft is provided with a screw thread. An
27 expansion cone can be engaged with the screw thread
28 on the shaft. The screw thread on the shaft is
29 typically a low-pitch screw thread, but can be a
30 high-pitch screw thread. The expansion cone is
31 typically capable of longitudinal movement along the

1 screw thread when the shaft is rotated relative to
2 the cone.

3

4 The screw thread on the shaft can typically provide
5 a gearing effect to the movement of the cone. A
6 low-pitch screw thread provides for slower movement
7 of the cone relative to the shaft, and can provide
8 relatively high radial expansion forces but slower
9 movement of the cone. A high-pitch screw thread
10 provides for faster movement of the cone relative to
11 the shaft, and can provide relatively lower
12 expansion forces but faster movement of the cone.
13 Thus, the pitch of the screw thread on the shaft can
14 be selected to provide larger or smaller expansion
15 forces as required.

16

17 The inflatable element typically acts as an anchor
18 for expansion of the perforated and/or non-
19 perforated portions. Inflation of the inflatable
20 element typically anchors the expander device at a
21 lower end of the non-perforated portion, and can be
22 used to isolate a pulling force that is typically
23 applied to the expanded perforated portion during
24 expansion of the non-perforated portion. The
25 anchoring and isolation provided by the inflatable
26 element substantially prevents the perforations in
27 the pre-expanded perforated portion from collapsing
28 during expansion of the non-perforated portions.

29

30 The shaft is typically provided with attachment
31 means (e.g. screw threads and/or a box or pin
32 connection) to facilitate attaching the apparatus to

1 a drill string, coiled tubing string, wireline or
2 the like. The drill string etc. can be used to
3 rotate the shaft relative to the inflatable member.
4 Optionally, the apparatus may include a motor or the
5 like to rotate the shaft. It will be appreciated
6 that a motor will not be required to rotate the
7 shaft where it is coupled directly to a drill
8 string. The motor typically comprises a mud motor
9 where the shaft is coupled to a coiled tubing
10 string.

11

12 The shaft can be rotated in the opposite direction
13 relative to the inflatable member to move the cone
14 back down the shaft to its original starting
15 position.

16

17 Alternatively, or additionally, the cone is
18 preferably provided with an engagement means that is
19 capable of engaging the screw thread on the shaft.
20 The cone is preferably provided with a release means
21 that is used to release the engagement means from
22 engagement with the screw thread on the shaft. The
23 engagement means may comprise first and second
24 portions that are provided with screw threads. The
25 first and second portions are preferably capable of
26 relative movement towards and/or away from one
27 another. The release means may comprise a threaded
28 rod or bolt that couples the first and second
29 portions together. Rotation of the threaded rod or
30 bolt in a first direction typically brings the first
31 and second portions together, whereas rotation of
32 the rod or bolt in a second direction, typically

1 opposite to the first, separates the two portions.
2 Thus, the cone can be selectively engaged and
3 disengaged from the screw thread provided on the
4 shaft. The cone may include a motor or the like to
5 rotate the threaded rod or bolt to move the portions
6 towards or away from one another.

7
8 The movement of the first and second portions can be
9 hydraulically or otherwise controlled. For example,
10 the release means may comprise a hydraulic cylinder
11 that can be used to move the first and second
12 portions towards and/or away from one another.

13
14 Alternatively, the cone may be provided with a motor
15 that rotates it in the opposite direction to move
16 the cone to the opposite end of the screw thread
17 (i.e. to return it to its original position).

18
19 The release mechanism may comprise other mechanisms
20 e.g. a self-releasing (high angle) or self-holding
21 (small angle) taper such as a Morse Standard Taper
22 Shank or collet-type release.

23
24 The expansion cone may be steel or ceramic or a
25 combination of these materials. The cone may also
26 be of tungsten carbide. The cone is typically
27 formed from a material that is harder than the
28 member that it has to expand. It will be
29 appreciated only the portions of the cone that
30 contact that contact the member need be of or coated
31 with the harder material.

32

1 The method typically includes the additional steps
2 of providing an expander device comprising an
3 inflatable element having a shaft rotatably attached
4 thereto, wherein at least a portion of the shaft is
5 provided with a screw thread, and an expansion cone
6 that is engaged with the shaft.

7
8 The method typically includes the additional steps
9 of attaching the expander device to a drill string,
10 coiled tubing string or the like; and inflating the
11 inflatable element to radially expand a portion of
12 the tubular member into contact with a second
13 conduit. The second conduit may be a casing, liner,
14 a formation around the borehole or the like.

15
16 The method typically includes the additional steps
17 of deflating the inflatable member and pulling or
18 pushing the expander device through the tubular
19 member to radially expand at least a portion thereof
20 to increase its outer diameter and/or its inner
21 diameter.

22
23 The method typically includes the additional steps
24 of arresting the travel of the expander device when
25 the cone reaches the non-perforated portion (or a
26 relatively in-expansile portion) of the tubular
27 member, inflating the inflatable member and rotating
28 the shaft against the inflatable member. Rotation
29 of the shaft typically causes the cone to move along
30 the screw thread as it is held stationary by contact
31 with an inner surface of the tubular member.

32

1 The method typically includes the additional steps
2 of rotating the shaft in the opposite direction to
3 move the cone back along the screw thread. This
4 provides a means of returning the cone to its
5 original starting position.

6
7 The method typically includes the additional steps
8 of releasing the engagement means to disengage the
9 cone from the shaft and allowing the cone to travel
10 back down the shaft.

11
12 The method typically includes the additional steps
13 of deflating the inflatable member and pulling or
14 pushing the expander device through the tubular
15 member to radially expand at least a portion thereof
16 to increase its outer diameter and/or its inner
17 diameter.

18
19 Optionally, the expansion cone may be double-sided.
20 In this embodiment, the expansion cone can be used
21 to radially expand the tubular member in both the
22 upward and downward directions. Use of the terms
23 "upward" and "downward" will be understood to relate
24 to a conventional vertical orientation of a
25 borehole. It will be appreciated that the invention
26 can also be used in deviated wells, and the terms
27 "upward" and "downward" are to be construed
28 accordingly, depending upon the orientation of the
29 well. It will be appreciated that "downward"
30 generally means away from the surface, and "upward"
31 generally means towards the surface. Optionally
32 also, the cone may comprise a plurality of fingers

1 that can be moved from a retracted to an expanded
2 configuration.

3
4 A second embodiment of expander device comprises a
5 rotary expansion mechanism and a solid expansion
6 cone located therebelow. The solid expansion cone
7 may be spaced-apart from the rotary expansion
8 mechanism (e.g. by a shaft or the like) or can be
9 integral therewith. The rotary expansion mechanism
10 typically comprises a cage having a plurality of
11 roller bearings attached thereto. The roller
12 bearings are preferably inclined with respect to a
13 longitudinal axis of the mechanism, typically at an
14 angle of around 20°, so that they form an expansion
15 cone on their outer surfaces. Other angles between
16 around 5° and 45° can also be used, although angles
17 outwith this range may also be used. However, the
18 preferred angle is around 20°.

19
20 The solid expansion cone is typically of steel or
21 ceramic, but can be a combination of these. The
22 solid expansion cone may also be of tungsten
23 carbide. The cone is typically of a material that
24 is harder than that of the member that is has to
25 expand. It will be appreciated only the portions of
26 the cone that contact that contact the member need
27 be of or coated with the harder material.

28
29 The rotary expansion mechanism may be rotated by
30 rotating the drill string. Alternatively, or
31 additionally, the rotary expansion mechanism may be
32 rotated by passing fluid (e.g. drilling mud) over,

1 across or through the expansion mechanism. The
2 roller bearings of the rotary expansion mechanism
3 may be attached to a turbine blade that imparts a
4 rotational force to the roller bearings when fluid
5 passes through, over or across the blade.

6
7 The method typically includes the additional steps
8 of rotating the rotary expansion mechanism and
9 pulling or pushing the apparatus through non-
10 perforated portions of the tubular member to impart
11 a radial expansion force thereto. The method
12 typically includes the additional step of pushing or
13 pulling the solid expansion cone through portions of
14 the tubular member that are slotted or perforated.

15
16 Optionally, the solid cone can be replaced with a
17 second rotary expansion mechanism.

18
19 Embodiments of the present invention shall now be
20 described, by way of example only, with reference to
21 the accompanying drawings, in which:-

22 Fig. 1 is a perspective view of a tubular
23 member that includes non-perforated portions
24 and a perforated portion;

25 Fig. 2 is a perspective view of an alternative
26 tubular member that includes non-perforated
27 portions and perforated portions;

28 Fig. 3 is part cross-sectional view a portion
29 of a first embodiment of apparatus for
30 expanding tubulars;

31 Fig. 4 is a cross-sectional view of a portion
32 of a borehole;

1 Fig. 5 is a cross-sectional view of a stacked
2 formation;

3 Fig. 6 is a cross-sectional view of a portion
4 of a borehole similar to that of Fig. 4; and
5 Fig. 7 is a part cross-sectional view of an
6 alternative embodiment of apparatus for
7 expanding tubulars.

8

9 Referring to the drawings, Fig. 1 shows a first
10 embodiment of a tubular member 10 (e.g. a portion of
11 casing, liner, drill pipe or other such member) that
12 is used to line or case a borehole (not shown). Use
13 of the term "tubular member" herein will be
14 understood to encompass any tubular member, such as
15 casing, liner, drill pipe etc.

16

17 Member 10 is preferably of a ductile material so
18 that it is capable of being plastically and/or
19 elastically deformed to expand an inner diameter
20 (ID) and/or an outer diameter (OD) thereof.

21 Alternatively, or additionally, tubular member 10
22 may also be capable of radial expansion under the
23 application of a radial expansion force.

24

25 Member 10 includes a perforated or slotted portion
26 12 that is approximately in a central portion of the
27 member 10, and two non-perforated portions 14, 16,
28 one on each side of the perforated portion 12. The
29 non-perforated portions 14, 16 typically house
30 attachment means (e.g. screw threads) that can be
31 used to couple the member 10 into a string of other
32 tubular members. The non-perforated portions 14, 16

1 provide a strong and reliable coupling between
2 successive tubular members.

3
4 The perforated portion 12 is typically used as a
5 sand screen at or near a payzone, a formation or a
6 well. The perforated portion 12 can also be used to
7 facilitate the recovery of hydrocarbons from the
8 payzone, formation or well, as the slots or
9 perforations allow the hydrocarbons to flow into the
10 member 10 so that they can be recovered to the
11 surface (not shown) in a conventional manner.

12
13 Fig. 2 shows an alternative tubular member 20
14 (similar to tubular member 10) that is provided with
15 two axially spaced-apart perforated portions 22, 24,
16 with non-perforated portions 26, 28 at each end, and
17 a further non-perforated portion 30 between the two
18 perforated portions 22, 24.

19
20 Tubular members 10, 20 can be used for many
21 different purposes, and are typically used in a
22 string of similar or other tubular members (not
23 shown). The string generally includes a number of
24 tubular members that are non-perforated with one or
25 more of the members 10, 20 or the like that have
26 perforations.

27
28 For example and with reference to Fig. 4, there is
29 shown a lower portion of a well or borehole that is
30 provided with a casing 50 at a lower end thereof. A
31 liner 52 (typically one or more non-perforated
32 tubular members) is hung off the bottom of the

1 casing 50 in a conventional manner. The liner 52 is
2 used to line a pre-drilled borehole 56 that extends
3 towards a payzone, formation or well, indicated
4 generally by 58, from which hydrocarbons can be
5 recovered.

6
7 The liner 52 is "tied back" to the casing 50 in a
8 conventional manner and can be cemented into place
9 by filling an annulus between the borehole 56 and an
10 outer surface of the liner 52 with cement 54.
11 Thereafter, a perforated member 60 (which could be
12 either member 10 (Fig. 1) or member 20 (Fig. 2) or
13 the like) is inserted through casing 50 and liner 52
14 so that an upper portion 60u of the member 60
15 overlaps a lower portion 52l of the liner 52, and
16 the member 60 is then radially expanded, as will be
17 described.

18
19 Referring to Fig. 5, there is shown a cross-
20 sectional view of a portion of a stacked reservoir
21 that typically has layers of different materials
22 that require to be isolated from one another. For
23 example, the stacked reservoir may have a lower
24 shingle or shale layer 70, with a sand or reservoir
25 layer 72 thereabove, a further shingle or shale
26 layer 74 above the sand or reservoir layer 72, and a
27 further sand or reservoir layer 76 below a third
28 shingle or shale layer 78.

29
30 The sand or reservoir layers 72, 76 typically
31 facilitate the recovery of hydrocarbons from the
32 surrounding formation that can be recovered to the

1 surface. In the example shown in Fig. 5, tubular
2 member 20 (Fig. 2) can be used to line or case this
3 particular portion of the stacked reservoir. The
4 perforated portions 22, 24 are axially aligned with
5 the sand layers 72, 76. The non-perforated portions
6 26, 30, 28 are axially aligned with the shale layers
7 70, 74, 78 respectively, so that they isolate the
8 shale layers 70, 74, 78, whereas the perforated
9 portions 22, 24 act as a sand screen and allow
10 hydrocarbons recovered from the sand or reservoir
11 layers 72, 76 to be recovered to the surface.

12

13 Fig. 6 shows a lower portion of a borehole that is
14 similar to that shown in Fig. 4. A casing 80 is
15 provided at a lower end of the borehole that
16 typically forms a string of such casings that
17 prevent the formation surrounding the borehole from
18 collapsing, and also facilitates the recovery of
19 hydrocarbons to the surface. A liner 82 (e.g. one
20 or more non-perforated tubular members) is hung off
21 the bottom of the casing 80 in a conventional
22 manner. The liner 82 is typically cemented into
23 place by filling an annulus between the borehole
24 (not shown) and an outer surface of the liner 82
25 with cement 84.

26

27 A perforated or slotted member 86 (e.g. member 20
28 (Fig. 2)) is attached at a lower end of the liner
29 82. The perforated member 86 is tied back to the
30 liner 82 by overlapping the liner 82 and the member
31 86 so that when the member 86 is radially expanded,
32 an outer surface of the member 86 contacts an inner

1 surface of the liner 82 to create a junction and a
2 seal, generally designated at 88.

3

4 As with Fig. 5, a lower end of the horizontal
5 borehole has a number of different portions, similar
6 to the stacked reservoir of Fig. 5 but in a
7 generally horizontal configuration. The borehole of
8 Fig. 6 has a first portion 90 from which
9 hydrocarbons may be recovered; a second portion 92
10 from which hydrocarbons cannot be recovered (e.g.
11 shale, shingle or the like); a third portion 94 from
12 which hydrocarbons may be recovered; a fourth
13 portion 96 from which hydrocarbons cannot be
14 recovered; and a fifth portion 98 from which
15 hydrocarbons may be recovered.

16

17 A combination of non-perforated and perforated
18 tubular members can be used to line the borehole.
19 In this particular example, the combination
20 comprises perforated portions 102, 106, 110 at the
21 (hydrocarbon producing) portions 90, 94, 98 and non-
22 perforated portions 104, 108 at the non-hydrocarbon
23 producing portion 92, 96.

24

25 It will be appreciated that the perforated portions
26 102, 106, 110 of member 86 may comprise tubular
27 members 10 (Fig. 1) that have been coupled to non-
28 perforated tubulars (e.g. lightweight pipe) 104, 108
29 using screw threads for example. Alternatively, the
30 various portions may comprise a single length with
31 alternate non-perforated and perforated portions,
32 similar to member 20 (Fig. 2).

1

2 The hydrocarbon producing portions 90, 94, 98 allow
3 hydrocarbons to flow into the combination of non-
4 perforated and perforated tubular members (i.e.
5 member 86), into the member 86 and thus they can be
6 recovered to the surface.

7

8 It will be noted that the members 10, 20, 60, 86 and
9 other combinations of non-perforated and perforated
10 tubular members can be difficult to expand radially
11 because the members include perforated portions and
12 non-perforated portions. The expansion force
13 required to radially expand perforated portions is
14 significantly less than that required to expand non-
15 perforated portions. The higher force exerted on
16 the non-perforated portion can collapse the expanded
17 perforated tubular that is coupled to the non-
18 perforated portion, because the very high force on
19 the non-perforated portion can pull or stretch the
20 perforated portion so that it collapses radially and
21 the perforations close up.

22

23 Note that the radial expansion of the members is
24 typically achieved by expanding the member "bottom-
25 up"; that is, the expander device that is used to
26 impart a radial expansion force is pushed or pulled
27 upwardly through the member from the lowest part to
28 be expanded. However, the member can also be
29 expanded top-down, provided that sufficient force
30 can be applied to the expander device by slacking
31 off weight above the device, or hanging off
32 sufficient weight below the expander device.

1

2 Fig. 3 shows a first embodiment of apparatus 150 for
3 expanding tubulars, in this embodiment the tubular
4 is a combination string of perforated and non-
5 perforated tubulars.

6

7 Apparatus 150 includes an inflatable element, such
8 as a packer 152 that is located at a lower end of
9 the apparatus 150. A bearing 154, such as a thrust
10 bearing, is located above the packer 152 and has a
11 shaft 156 rotatably attached to it. The bearing 154
12 allows the shaft 156 to rotate whilst the packer 152
13 remains stationary. Shaft 156 is part threaded,
14 preferably with a relatively low-pitch screw thread
15 156t, and an expansion cone 158 engages with the
16 screw thread 156t on the shaft 156, the cone 158
17 being capable of longitudinal movement up and down
18 the threaded portion of the shaft 156. A drive
19 means 160 (e.g. a motor or the like) for rotating
20 the shaft 156 is optionally provided at an upper end
21 of the shaft 156. An upper end of the drive means
22 160 is typically attached to a drill string, coiled
23 tubing string or the like.

24

25 It will be appreciated that the drive means 160 may
26 not be required where the shaft 156 is coupled
27 directly to a drill string, as the string can be
28 rotated in a conventional manner to rotate the shaft
29 156. In this case, the shaft 156 would be provided
30 with attachment means (e.g. screw threads) so that
31 it can be attached to the drill string.

32

1 In use, the apparatus 150 is located in a liner 162,
2 casing or the like that is to be radially expanded
3 to increase its outer diameter (OD) and/or inner
4 diameter (ID). The packer 152 and the expansion
5 cone 158 are located in a pre-expanded portion 162e
6 of the liner 162 before the liner 162 is run into
7 the borehole to the required depth. The pre-
8 expanded portion 162e is typically sufficiently
9 expanded to allow the packer 152 to be located
10 therein, but is generally not fully expanded so that
11 the liner 162 can be run into the borehole.

12

13 Once at the required depth, the packer 152 is
14 inflated using any conventional means to expand the
15 pre-expanded portion 162e radially outwards so that
16 an outer surface of the pre-expanded portion 162e
17 contacts an inner surface of a second conduit. The
18 second conduit may be an uncased formation, pre-
19 installed casing, liner, or the like. The further
20 expansion of the pre-expanded portion 162e can act
21 as an anchor for the liner 162 as it is radially
22 expanded by the cone 158.

23

24 Optionally, the packer 152 may be deflated and moved
25 within the liner 162, where it is re-inflated to
26 radially expand the liner 162 into contact with the
27 second conduit. The additional expansion of the
28 liner 162 serves to increase the surface area of the
29 outer surface of the liner 162 that acts as an
30 anchor.

31

1 The packer 152 is then deflated and the cone 158 is
2 pulled through the liner 162 to radially expand the
3 liner 162 in a known manner. The cone 158 may be
4 pulled through the liner 162 using the drill string,
5 coiled tubing string or the like to which it is
6 attached. When the cone 158 reaches a non-
7 perforated portion of the liner 162, this will be
8 indicated by an increase in the force required to
9 expand the liner 162. At this point, the packer 152
10 is re-inflated to act as an anchor for the apparatus
11 150. Thereafter, the shaft 156 is rotated by
12 actuation of the motor 160, or by rotation of the
13 drill string to which shaft 156 is attached. The
14 shaft 156 is thus rotated against the packer 152
15 using the bearing 154.

16

17 It will be appreciated that the packer 152 can be
18 detached from the shaft 156 and left at the lower
19 end of the liner 162 to act as an anchor during
20 expansion of the liner 162. When the cone 158
21 reaches a non-perforated portion, the cone 158 and
22 shaft 156 are lowered until the packer 152 engages
23 the shaft 156, and the apparatus 150 returned to the
24 non-perforated portion, where the packer 152 is re-
25 inflated.

26

27 The cone 158 is located on the low-pitch screw
28 thread 156t on the shaft 156 and is prevented from
29 rotating with the shaft 156 by friction on its OD
30 where the cone 158 contacts the liner 162. As the
31 cone 158 is prevented from rotating by contact with
32 the liner 162, it will move up the screw thread on

1 shaft 156 as the shaft 156 rotates, and thus expand
2 the liner 162 over the non-perforated portion.

3
4 It will be appreciated that it is preferable to have
5 the length of the portion of the shaft 156 that is
6 provided with the screw thread 156t at least as long
7 as the non-perforated portion of the liner 162. It
8 is preferable to have the length of the screw thread
9 156t slightly longer than that required to expand
10 the non-perforated portion. The packer 152 acts as
11 both an anchor for the expansion of the non-
12 perforated portion and can also help prevent the
13 expanded perforated portion therebelow from
14 collapsing by keeping it open against the induced
15 collapsing force.

16
17 Once the cone 158 has travelled the length of the
18 screw thread 156t, the shaft 156 can be rotated in
19 the opposite direction or the force preventing the
20 cone 158 from rotating is removed, allowing the cone
21 158 to travel back down the screw thread 156t to its
22 original starting position.

23
24 The cone 158 can typically be provided with at least
25 a portion of screw thread that interengages with the
26 thread 156t on the shaft 156. The thread on the
27 cone 158 could be provided on two or more segments
28 that are capable of being moved towards and away
29 from one another. For example, two portions may be
30 coupled using a threaded shaft (e.g. a bolt) that
31 can be rotated to move the two portions towards and
32 away from one another. One of the portions could be

1 provided with a threaded nut that interengages with
2 the threads on the bolt. The threaded bolt may also
3 be provided with a quick-release mechanism, such as
4 a lever that is moved to disengage the nut from the
5 bolt. This arrangement is similar to that used in a
6 common bench vice.

7
8 In use, the bolt may be driven by a motor located
9 within or as part of the cone 158. Rotation of the
10 bolt in a first direction would draw the two
11 portions together and thus the cone 158 would be
12 threadedly engaged with the shaft 156. Rotation of
13 the bolt in a second direction, typically opposite
14 to the first direction, would move the two portions
15 away from one another, thus releasing the cone 158
16 from the shaft 156 and allowing it to travel back to
17 its original starting position without rotation
18 (e.g. under the force of gravity or as the shaft 156
19 is pulled out of the borehole).

20
21 Alternatively, the two portions may be coupled using
22 a hydraulic cylinder or the like that can be
23 actuated and de-actuated to move the portions
24 towards and away from one another.

25
26 As a further alternative, other release mechanisms
27 could be used including a self-releasing (high
28 angle) or self-holding (small angle) taper such as a
29 Morse Standard Taper Shank or collet-type release.

30
31 With the cone 158 back in its original position, it
32 can be pulled through the perforated portion until a

1 non-perforated portion is reached, whereupon the
2 packer 152 is then inflated and the shaft 156
3 rotated to move the cone 158 through the liner to
4 expand it, as previously described.

5
6 The cone 158 may be double-sided, that is, the cone
7 158 can be provided with a face that can be used to
8 expand the liner or the like in both upward and
9 downward directions. Also, two packers 152 could be
10 used; one that travels with the cone 158 as
11 described above, and a second that is used to anchor
12 the liner 162 at a lower end thereof continuously
13 whilst the remainder of the liner 162 is radially
14 expanded, as described above.

15
16 It would be advantageous to have a segmented cone
17 that is provided with a plurality of fingers that
18 are capable of being moved from a retracted
19 configuration to an expanded configuration. Outer
20 surfaces of the fingers can provide one or more
21 expansion cones so that when the fingers are in the
22 expanded position, the cone can be used to radially
23 expand the liner 162. However, the cone can be run
24 into the borehole, liner etc in a collapsed state
25 (i.e. with the fingers retracted). This is
26 advantageous as the liner 162 need not be provided
27 with a pre-expanded portion 162e, and the apparatus
28 150 can be run into a liner that has previously been
29 located in the borehole. The fingers of the cone
30 can then be moved to the radially expanded position
31 so that the liner or the like can be expanded.
32

1 It will be noted that where an expandable cone is
2 used, the packer 152 can be used to inflate a lower
3 portion of the liner 162 (i.e. at the pre-expanded
4 portion 162e) to provide an anchor for the liner
5 162. Thereafter, the packer 152 is deflated and
6 moved upwardly to a second position, above the
7 first, and inflated again. The second expanded
8 portion of liner 162 facilitates opening of the
9 fingers of the cone more easily into the expanded
10 configuration.

11

12 Referring to Fig. 7, there is shown an alternative
13 apparatus 200 for the radial expansion of a mixed
14 string of perforated and non-perforated tubulars.

15

16 Apparatus 200 is particularly suited for use when
17 expanding portions of non-perforated tubular 202 and
18 perforated or slotted tubular 204. It will be
19 generally appreciated that tubulars 202, 204 may be
20 casing, liner or the like. It will also be
21 appreciated that tubular 202, 204 may comprise a
22 plurality of discrete lengths of tubular member that
23 are coupled together (e.g. by welding or screw
24 threads).

25

26 Apparatus 200 includes a rotary expansion mechanism
27 206 that typically comprises a cage 208 having a
28 number of roller bearings 210 attached thereto. The
29 roller bearings 210 are inclined (typically at
30 around 20° with respect to a longitudinal axis of
31 the apparatus 200) so that they form an expansion
32 cone on their outer surfaces. Other angles between

1 around 5° and 45° can also be used, although angles
2 outwith this range may also be used. However, the
3 preferred angle is around 20°.

4
5 The rotary expansion mechanism 206 is primarily used
6 to transmit radial and pull force into a radial
7 expansion force, instead of only pull force. Thus,
8 the rotary expansion mechanism 206 has the advantage
9 of reducing friction.

10
11 An upper portion of the rotary expansion mechanism
12 206 is typically provided with attachment means (not
13 shown) such as screw threads or the like to enable
14 the apparatus 200 to be attached to a drill string,
15 coiled tubing string or the like.

16
17 A solid expansion cone 212 is attached below the
18 rotary expansion mechanism 206, typically via a
19 shaft 214 or the like. It will be understood that
20 the solid expansion cone 212 may be integral with
21 the rotary expansion mechanism 206. The solid
22 expansion cone 212 is typically of steel or ceramic,
23 but may be a combination of steel and ceramic,
24 although it may also be made of tungsten carbide or
25 the like. The solid expansion cone 212 is typically
26 of a material that is harder than the member that it
27 has to expand. As before, only the portion of the
28 cone 212 that come into contact with the tubulars
29 202, 204 need be of or coated with the harder
30 material.

31

1 The perforated or slotted tubular 202 is provided
2 with a pre-expanded portion 202e in which a portion
3 of the apparatus 200 (typically the solid expansion
4 cone 212) is located. Similarly, the non-perforated
5 tubular 204 is provided with a pre-expanded portion
6 204e that is attached to pre-expanded portion 202e
7 in use. Tubulars 202 and 204 can be coupled
8 together using any conventional means, such as screw
9 threads or the like. Conventional pin and box
10 connections may be used, for example.

11
12 In use, the slotted or perforated tubular 202 is
13 lowered into the borehole (not shown) to the
14 required depth, and may be held in place using any
15 conventional means (e.g. a packer or the like) if
16 required. Thereafter, the apparatus 200 is attached
17 to a string 216 of drill pipe or the like that forms
18 a conventional drill string. The apparatus 200 is
19 attached to the drill string 216 using any
20 conventional means. It will be appreciated that
21 apparatus 200 could also be attached to a coiled
22 tubing string or the like.

23
24 The drill string 216 with the apparatus 200 attached
25 thereto is then lowered into the borehole until the
26 solid expansion cone 212 is located within the pre-
27 expanded portion 202e of the perforated or slotted
28 tubular 202. The non-perforated tubular 204 is then
29 lowered into the borehole and the pre-expanded
30 portion 204e is threadedly engaged with the pre-
31 expanded portion 202e of the perforated or slotted
32 tubular 202.

1
2 It will be appreciated that the apparatus 200 can be
3 located in the pre-expanded portions 202e, 204e and
4 the tubulars 202, 204 threadedly coupled at the
5 surface so that the entire assembly can be lowered
6 into the borehole.

7
8 The rotary expansion mechanism 206 is then rotated,
9 typically by rotating the drill string 216. Where
10 the apparatus 200 is coupled to a coiled tubing
11 string, a mud motor or the like (not shown)
12 typically forms part of the string and can be used
13 to rotate the apparatus 200 by actuation of the
14 motor. The rotary expansion mechanism 206 may also
15 be rotated by the flow of drilling fluid (e.g. mud)
16 through, over or across the mechanism 206. For
17 example, the rotary expansion mechanism 206 may be
18 provided with a turbine blade (not shown) that is
19 coupled to the rotary bearings 210 so that drilling
20 fluid that passes over the turbine blades imparts a
21 rotational force to the rotary bearings 210.

22
23 As the rotary expansion mechanism 206 is rotated, it
24 is pulled upwards through the non-perforated tubular
25 204 to radially expand it. The inclination of the
26 roller bearings 210 of the rotary expansion
27 mechanism 206 provides an expansion force that
28 causes a radial plastic deformation of the non-
29 perforated tubular 204 to radially expand its outer
30 diameter and/or its inner diameter. It will be
31 appreciated that use of the term "radial plastic
32 deformation" is understood to be the use of an

1 expander device (e.g. the rotary expansion mechanism
2 206 or cone 212) that is pushed or pulled through
3 the tubular 204 to impart a radial expansion force
4 to the tubular 204 so that both the ID and the OD of
5 the tubular 204 increases.

6
7 Once the non-perforated tubular 204 has been
8 completely expanded, the drill string 216 is then
9 lowered until the solid cone 212 contacts the
10 perforated or slotted tubular 202. The cone 212 is
11 then forced through the perforated or slotted
12 tubular 202 by, for example, slacking off weight
13 above the apparatus 200 so that the weight of the
14 string 216 and the apparatus 200 is used to push
15 down on the cone 212. In this way, the tubular 202
16 is radially expanded to increase its OD and its ID.

17
18 It will be appreciated that the drill string 216 may
19 be rotated, or the apparatus 200 otherwise rotated,
20 so that the cone 212 rotates during use.

21
22 After the perforated or slotted tubular 202 has been
23 expanded, the drill string 216 and the apparatus 200
24 is then removed from the borehole in the
25 conventional manner (e.g. it is pulled out of hole).

26
27 It will be appreciated that the solid cone 212 can
28 be replaced with another rotary expansion mechanism
29 206 that can be used to expand the slotted or
30 perforated tubular 202. Where the combination
31 string comprises a single length of non-perforated
32 tubular above a single length of perforated or

1 slotted tubular, the rotary expansion mechanism 206
2 can be used for upward expansion of the non-
3 perforated tubular, and a solid cone 212 used for
4 the downward expansion of the perforated or non-
5 perforated tubular. Alternatively, a solid cone
6 (e.g. cone 212) can be used to expand both. For
7 multiple lengths of non-perforated and perforated or
8 slotted tubular, it is preferable to use a rotary
9 expansion mechanism 206 for expansion in both the
10 upward and downward directions.

11

12 It is possible that expanding a slotted tubular that
13 has non-perforated portions can be done with the
14 member in compression. The slotted portion can be
15 expanded in this situation and it is possible that
16 the expansion force could increase by a factor of 10
17 or more at the non-perforated portions without
18 damaging the expanded perforated portion.

19

20 Certain embodiments of the apparatus and method
21 allow the radial expansion of a combination string
22 of both perforated or slotted tubulars. Certain
23 embodiments also allow the combination string to be
24 radially expanded in only a single pass of the
25 apparatus through the combination string, thus
26 providing significant savings in terms of costs and
27 rig time.

28

29 Modifications and improvements may be made to the
30 foregoing without departing from the scope of the
31 present invention.

32

1 CLAIMS

2

3 1. Apparatus for expanding a tubular member
4 comprising an expander device (150, 200) that is
5 capable of generating different radial expansion
6 forces to expand respective portions (12, 14, 16,
7 22, 24, 26, 28, 30, 102, 104, 106, 108, 110) of the
8 tubular member (10, 20, 60, 86, 162, 202, 204).

9

10 2. Apparatus according to claim 1, wherein the
11 expander device (150, 200) includes an expansion
12 cone (158, 206, 212).

13

14 3. Apparatus according to claim 2, wherein the
15 expander device (150) further includes an inflatable
16 element (152) having a shaft (156) rotatably
17 attached thereto.

18

19 4. Apparatus according to claim 3, wherein the
20 shaft (156) can rotate relative to the inflatable
21 member (152).

22

23 5. Apparatus according to claim 3 or claim 4,
24 wherein the inflatable member comprises a packer
25 (152).

26

27 6. Apparatus according to any one of claims 3 to
28 5, wherein at least a portion of the shaft (156) is
29 provided with a screw thread (156t).

30

1 7. Apparatus according to claim 6, wherein the
2 expansion cone (158) can engage the screw thread
3 (156t) on the shaft (156).
4

5 8. Apparatus according to claim 7, wherein the
6 screw thread (156t) on the shaft (156) is a low-
7 pitch screw thread (156t).
8

9 9. Apparatus according to claim 7 or claim 8,
10 wherein the expansion cone (158) is capable of
11 longitudinal movement along the screw thread (156t)
12 when the shaft (156) is rotated relative to the cone
13 (158).
14

15 10. Apparatus according to any one of claims 3 to
16 9, wherein the inflatable element (152) acts as an
17 anchor for expansion of perforated and/or non-
18 perforated portions (12, 14, 16, 22, 24, 26, 28, 30,
19 102, 104, 106, 108, 110) of the tubular member (10,
20 20, 60, 86, 162, 202, 204).
21

22 11. Apparatus according to any one of claims 3 to
23 10, wherein the inflatable element (152) isolates a
24 pulling force applied to an expanded perforated
25 portion (12, 22, 24, 102, 106, 110) during expansion
26 of a non-perforated portion (14, 16, 26, 28, 30,
27 104, 108) of the tubular member (10, 20, 60, 86,
28 162, 202, 204).
29

30 12. Apparatus according to claim 1, wherein the
31 expander device (200) comprises a rotary expansion

1 mechanism (206) and a solid expansion cone (212)
2 attached thereto.
3

4 13. Apparatus according to claim 12, wherein the
5 rotary expansion mechanism (206) comprises a cage
6 (208) having a plurality of roller bearings (210)
7 attached thereto.
8

9 14. Apparatus according to claim 13, wherein the
10 roller bearings (210) are inclined with respect to a
11 longitudinal axis of the mechanism (206) so that
12 they form an expansion cone on their outer surfaces.
13

14 15. Apparatus according to claim 14, wherein the
15 roller bearings (210) are inclined at an angle of
16 around 20°.
17

18 16. Apparatus according to any one of claims 12 to
19 15, wherein the rotary expansion mechanism (206) is
20 rotatable.
21

22 17. Apparatus according to claim 16, wherein the
23 rotary expansion mechanism (206) is rotatable by
24 rotating a drill string (216), or by passing fluid
25 over, across or through the expansion mechanism
26 (206).
27

28 18. Apparatus according to any preceding claim,
29 wherein the respective portions comprise first and
30 second portions (12, 14, 16, 22, 24, 26, 28, 30,
31 102, 104, 106, 108, 110).
32

1 19. Apparatus according to claim 18, wherein the
2 first portion includes at least one perforated
3 portion (12, 22, 24, 102, 106, 110), and the second
4 portion includes at least one non-perforated portion
5 (14, 16, 26, 28, 30, 104, 108).
6

7 20. Apparatus according to any preceding claim,
8 wherein the tubular member (10, 20, 60, 86, 162,
9 202, 204) comprises a string of discrete members
10 having perforated (12, 22, 24, 102, 106, 110) and
11 non-perforated portions (14, 16, 26, 28, 30, 104,
12 108).
13

14 21. A method of expanding a tubular member, the
15 member including first and second portions (12, 14,
16 16, 22, 24, 26, 28, 30, 102, 104, 106, 108, 110),
17 the method comprising the steps of running the
18 tubular member (10, 20, 60, 86, 162, 202, 204) into
19 a borehole and radially expanding the first and
20 second portions (12, 14, 16, 22, 24, 26, 28, 30,
21 102, 104, 106, 108, 110) in the borehole using an
22 expander device (150, 200), wherein different radial
23 expansion forces are exerted on the first and second
24 portions (12, 14, 16, 22, 24, 26, 28, 30, 102, 104,
25 106, 108, 110) respectively.
26

27 22. A method according to claim 21, wherein the
28 method includes the additional step of providing an
29 expander device (150) comprising an inflatable
30 element (152) having a shaft (156) rotatably
31 attached thereto, wherein at least a portion of the
32 shaft (156) is provided with a screw thread (156t),

1 and an expansion cone (158) that is engaged with the
2 shaft (156).

3

4 23. A method according to claim 22, wherein the
5 method includes the additional steps of attaching
6 the expander device (150) to a drill string or
7 coiled tubing string, and inflating the inflatable
8 element (156) to radially expand a portion (162e) of
9 the tubular member (162) into contact with a second
10 conduit.

11

12 24. A method according to claim 23, wherein the
13 method includes the additional steps of deflating
14 the inflatable member (152) and pulling or pushing
15 the expander device (158) through the tubular member
16 (162) to radially expand at least a portion thereof
17 to increase its outer diameter and/or its inner
18 diameter.

19

20 25. A method according to claim 24, wherein the
21 first portion comprises one or more perforated
22 portions (12, 22, 24, 102, 106, 110), the second
23 portion comprises one or more non-perforated
24 portions (14, 16, 26, 28, 30, 104, 108), and the
25 method includes the additional steps of arresting
26 the travel of the expander device when the cone
27 reaches the second portion (14, 16, 26, 28, 30, 104,
28 108) of the tubular member (162), inflating the
29 inflatable member (152) and rotating the shaft (156)
30 against the inflatable member (152).

31

1 26. A method according to claim 25, wherein
2 rotation of the shaft (152) causes the cone (158) to
3 move along the screw thread (156t) as it is held
4 stationary by contact with an inner surface of the
5 tubular member (162).

6
7 27. A method according to claim 25 or claim 26,
8 wherein the method includes the additional step of
9 rotating the shaft (156) in the opposite direction
10 to move the cone (158) back along the screw thread
11 (156t).

12
13 28. A method according to claim 27, wherein the
14 method includes the additional steps of deflating
15 the inflatable member (156) and pulling or pushing
16 the expander device (150) through the tubular member
17 (152) to radially expand at least a portion thereof
18 to increase its outer diameter and/or its inner
19 diameter.

20
21 29. A method according to claim 21, wherein the
22 method typically the additional steps of providing
23 an expander device (200) comprising a rotary
24 expansion mechanism (206) and a solid expansion cone
25 (212).

26
27 30. A method according to claim 29, wherein a first
28 tubular member (202) includes one or more perforated
29 portions, a second tubular member (204) includes one
30 or more non-perforated portions, and the method
31 includes the additional steps of rotating the rotary
32 expansion mechanism (206) and pulling or pushing the

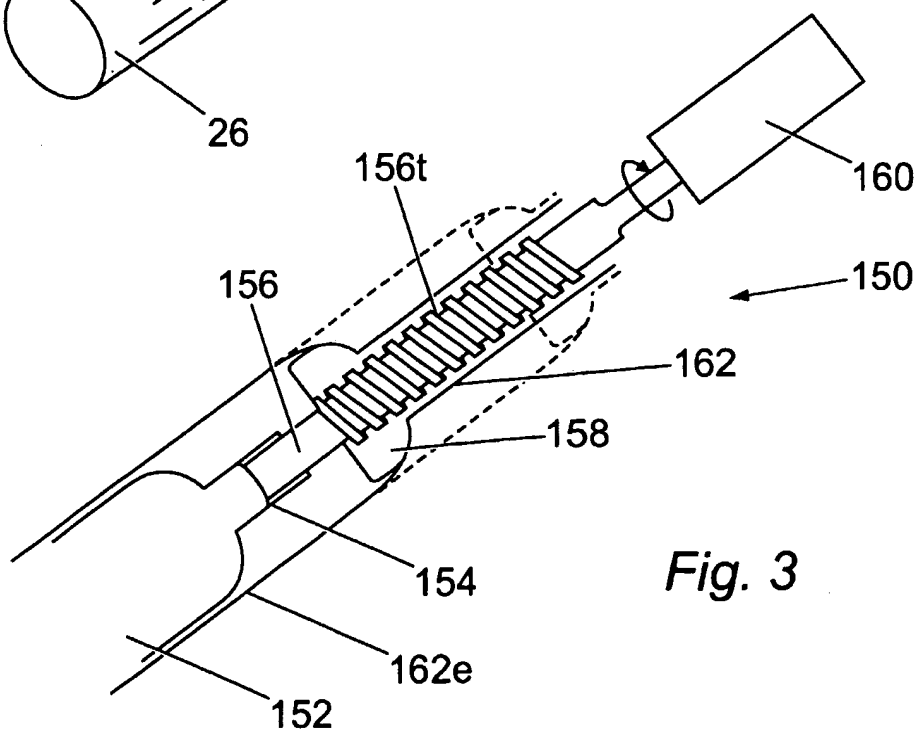
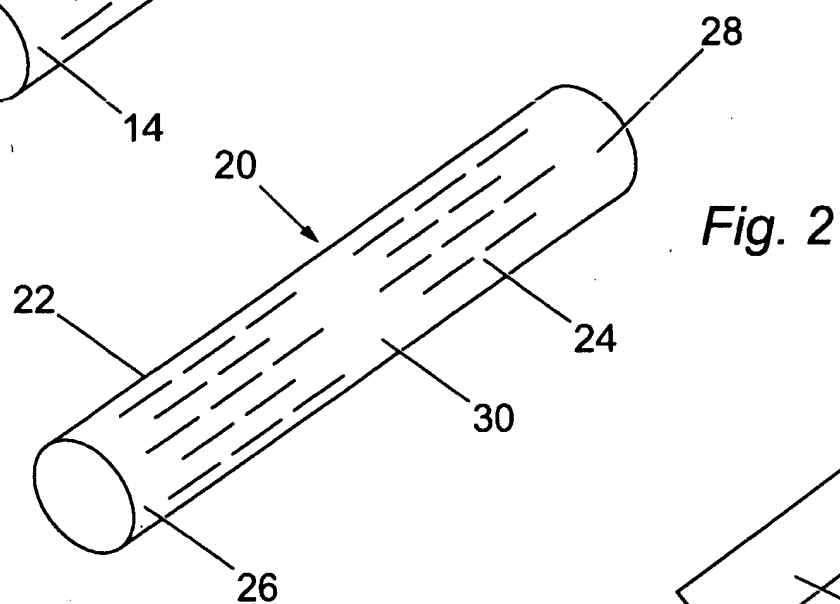
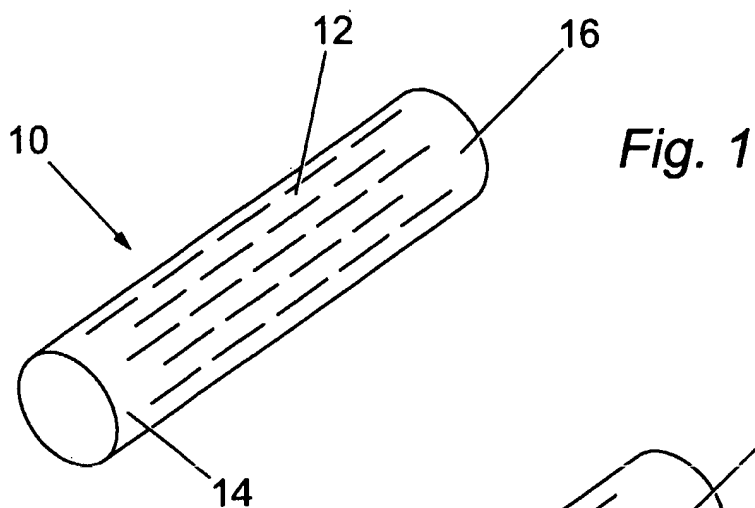
1 device (200) through the second tubular (204) to
2 impart a radial expansion force thereto.

3

4 31. A method according to claim 30, wherein the
5 method includes the additional step of pushing or
6 pulling the solid expansion cone (212) through the
7 second tubular member (202).

8

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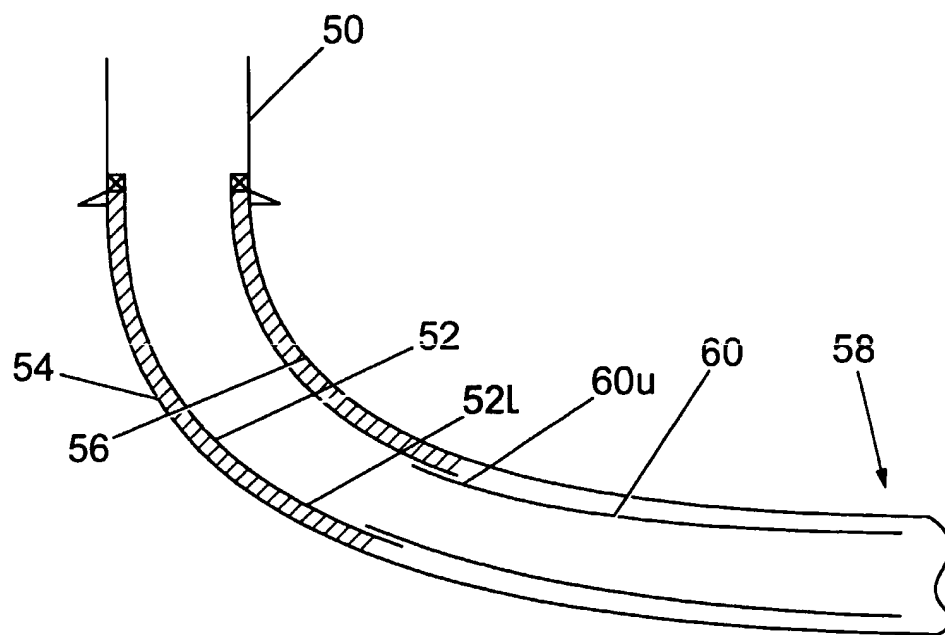


Fig. 4

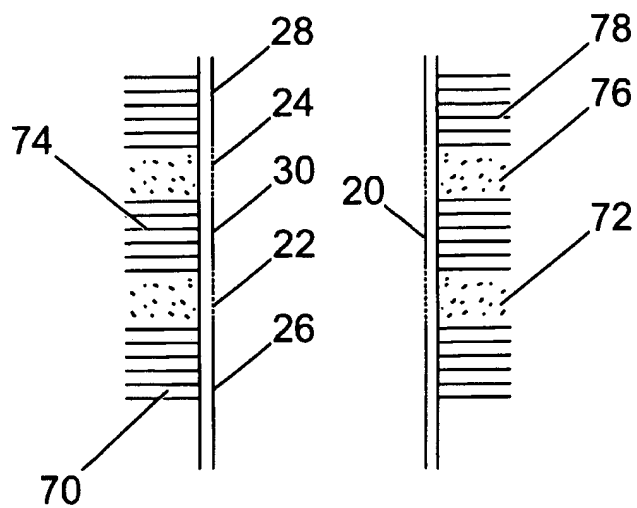


Fig. 5

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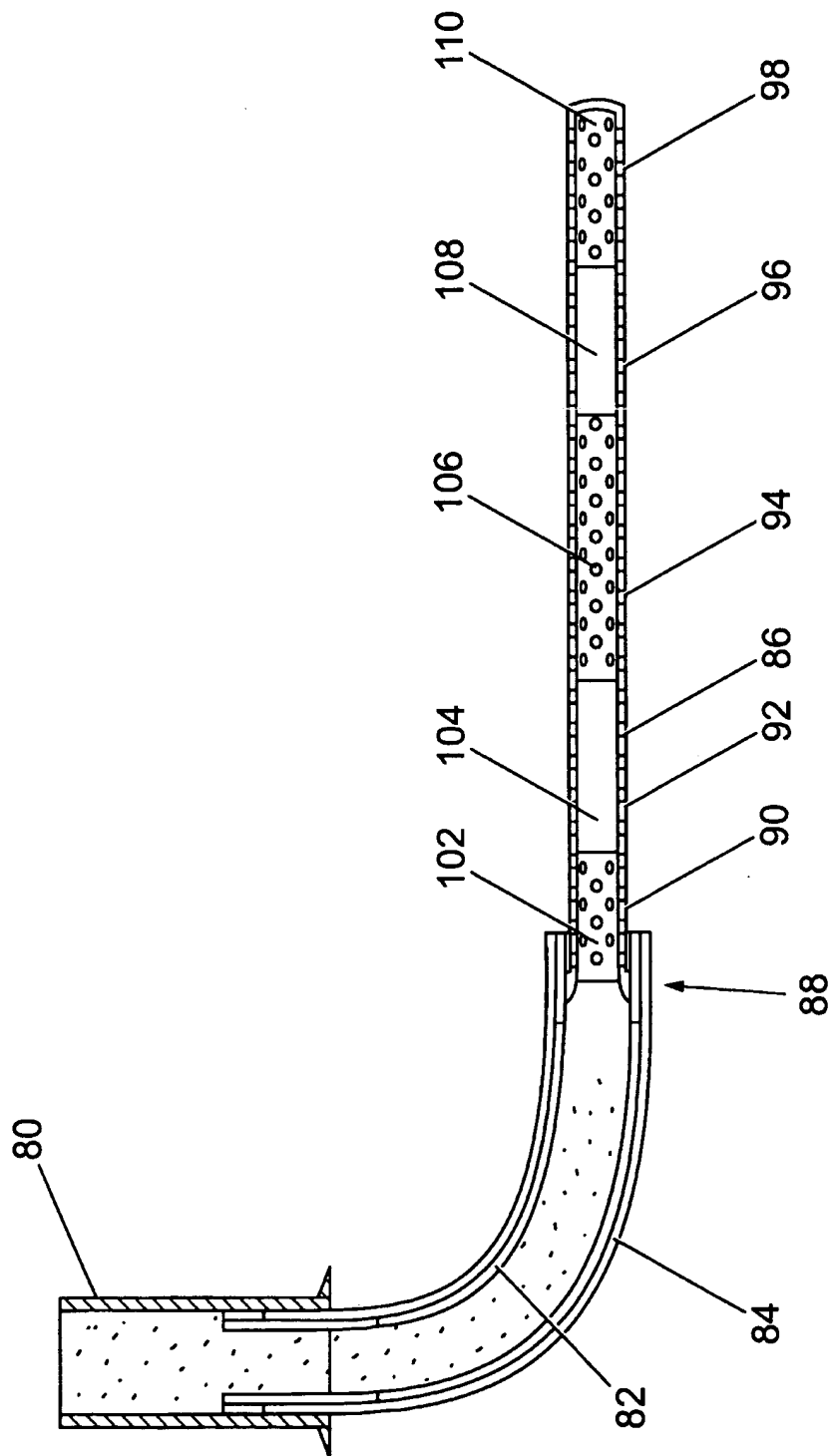


Fig. 6

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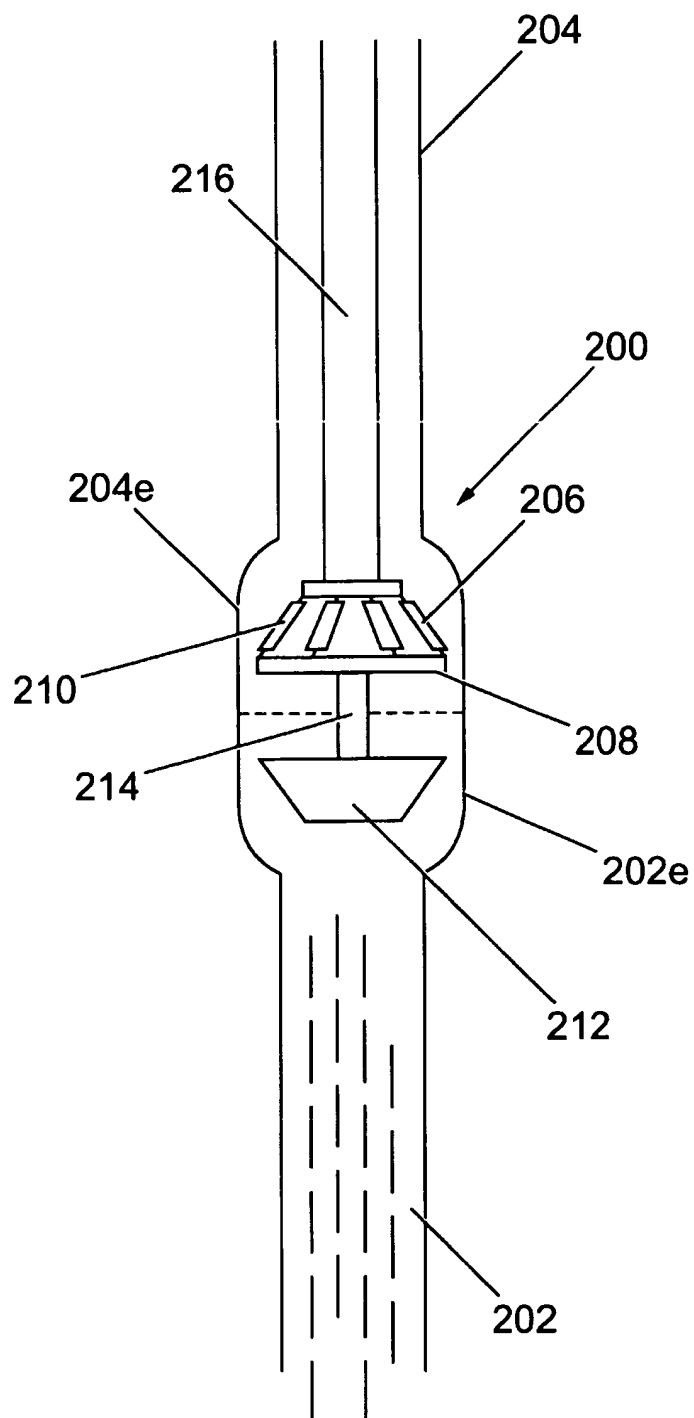


Fig. 7

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/GB 02/03734

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 B21D39/20 E21B43/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B21D E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

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A	abstract; figures	5, 21, 22
X	FR 1 142 975 A (SZEBO LASZLO) 25 September 1957 (1957-09-25)	1, 2, 12-16, 18-20
A	figures	3, 4, 6, 10
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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

5 November 2002

Date of mailing of the international search report

15/11/2002

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INTERNATIONAL SEARCH REPORT

International Application No.

PCT/GB 02/03734

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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